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TITLE: International Conference on Terahertz Electronics [8th], Held in Darmstadt, Germany on 28-29 September 2000

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MICROMACHINED PLANAR ANTENNAS FOR D-BAND FREQUENCIES

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Abstract

The fabrication of different planar antenna structures using micromachining techniques is described. The antenna patches are based on thin dielectric HMDSN membranes deposited by plasmapolymerization and fabricated by structuring the underlying silicon. Both antennas and CPW-feedlines are composed of two stacked KOH-etched silicon-layers. Different transitions from membrane-based coplanar waveguides to multi-layer antenna structures have been fabricated and characterized around 125 GHz.

Introduction

The structure of coplanar waveguides on thin dielectric membranes allows single-mode TEM wave propagation over a wide frequency range, almost negligible dispersion, and very low dielectric losses [4]. Coplanar waveguides on thin HMDSN-membranes have already been fabricated and characterized for D-band frequencies. They show a very low attenuation of about 0.1 dB/mm. A transition from membrane-based coplanar waveguide to rectangular waveguide has also been fabricated for D-band exhibiting low losses [1], [2]. Based on these results, two different planar antenna structures at D-band frequencies have been developed for power combining applications. The design and numerical results are presented in [3]. The manufacturing of the planar antennas on thin HMDSN-membranes is described below. The antennas consist of two stacked KOH-etched silicon layers fed by membrane-based coplanar waveguides. The membranes deposited from plasma-polymerized HMDSN were fabricated by structuring the 300 μm thick, low-resistive silicon below with micromachining techniques. The radiation pattern of a coplanar

fed microstrip probe horn antenna has been measured. Although the fabricated structure is based on a non-optimized design, it shows satisfactory far-field characteristics around 125 GHz.

Slot-Coupled CPW-Fed Patch Antenna

The structure is composed of two stacked micromachined silicon layers as shown in figure 1. The bottom layer contains the coplanar feedline which merges into a coupling slot. Both the coplanar feedline and the coupling slot are based on a 4 μm thin HMDSN-membrane.

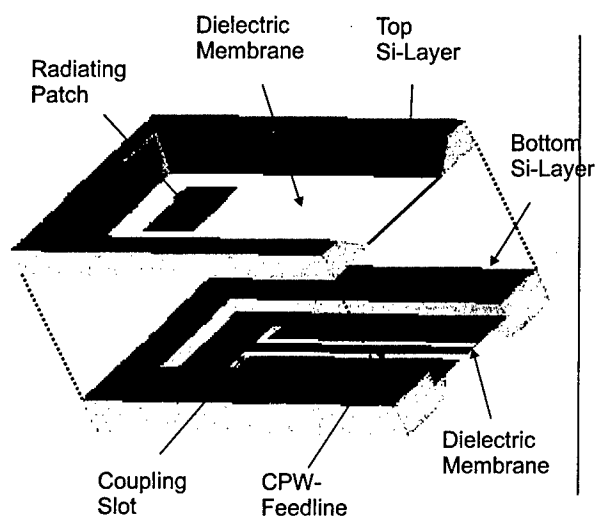


Figure 1: Structure of a slot coupled CPW-fed patch antenna.

The coplanar feedline is coupled to rectangular waveguide using the transition described in [1]. The membrane-based transition consists of two cascaded transitions, the first from rectangular waveguide to microstrip line followed by a taper from microstrip

to coplanar line. To form the ground plane of the membrane-based microstrip line the metallic surface of the test fixture is used. Therefore the height of the bottom layer has to be smaller than $100\text{ }\mu\text{m}$.

On the upper layer a radiating patch is placed on a $4\text{ }\mu\text{m}$ thin HMDSN-membrane. In the stacked structure, the radiating patch is centered exactly above the coupling slots. The gap between both layers is around $65\text{ }\mu\text{m}$. The gap is fabricated by structuring the upper side of the bottom silicon layer by plasma etching. Using low pressure chemical vapour deposition the silicon is cladded by a 200 nm thick Si_3N_4 -film. Subsequently, the $4\text{ }\mu\text{m}$ thick HMDSN film is grown by plasma-polymerization and annealed at 200°C . A 750 nm thick titanium/gold layer is sputtered and structured by wet chemical etching to form the coplanar waveguide and the coupling slot. The backside Si_3N_4 is opened by a plasma etching process serving as a mask on the silicon substrate.

Next the underlying silicon is etched to a depth of $100\text{ }\mu\text{m}$ in an alkaline KOH-solution. During this process the upper surface with the coplanar lines and the coupling slots is protected. Afterwards, the Si_3N_4 mask is removed by a plasma etching process. Employing the KOH-solution again, the silicon below the membrane is thinned to a few μm . During this fabrication step the upper surface is also protected. The remaining silicon and the Si_3N_4 are finally removed by a plasma etching process.

The upper layer is much easier to manufacture in comparison with the bottom layer, because the thickness of the substrate can be kept at $300\text{ }\mu\text{m}$. Furthermore, the upper surface of the layer is planar, because the gap between the layers is structured only in the bottom layer. The fabrication reduces to the evaporation of Si_3N_4 on a silicon substrate followed by the deposition and annealing of a $4\text{ }\mu\text{m}$ thick HMDSN film. Appropriate to the fabrication of the bottom layer described above, a titanium/gold film is sputtered and structured by wet chemical etching. Afterwards the Si_3N_4 is opened and the underlying silicon is removed up to a few μm in a KOH-solution while the upper surface is protected. At last the remaining silicon is removed by a plasma etching process.

Finally, the single manufactured layers are stacked and connected with fluid-silver.

CPW-Fed Microstrip Probe Micromachined Horn Antenna

Figure 2 shows a second type of planar antennas using thin dielectric membranes. The structure is based on the transition from coplanar waveguide on

thin HMDSN-membrane to conventional rectangular waveguide presented in [1]. The coplanar line is first tapered to a microstrip line. Afterwards, a transition from microstrip line to rectangular waveguide consisting of a nearly triangular patch placed in the E-plane of the coplanar waveguide is realized. To minimize the field distortion caused by the test fixture the direction of beam has to be perpendicular with respect to the test fixture surface. Therefore, a small KOH-etched, low-resistive silicon cuboid is used. The position of the bottom side of the cuboid is about $100\text{ }\mu\text{m}$ above the HMDSN-membrane, so this surface is used as ground plane of the microstrip line. The cavity sidewalls of the micromachined silicon substrate and the small silicon cuboid operate as a micromachined horn.

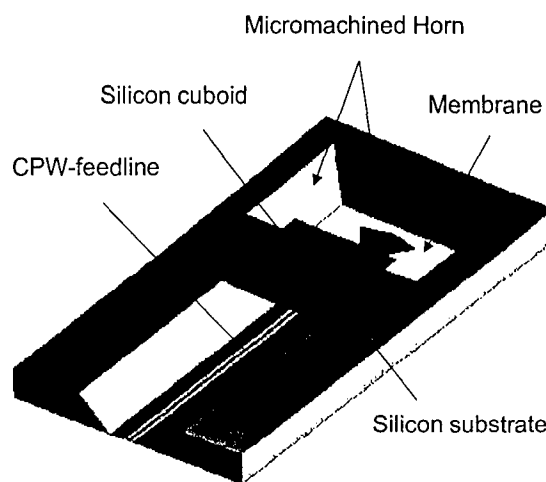


Figure 2: Structure of a microstrip probe micromachined horn antenna.

In principle, the fabrication of this antenna structure is identical compared with the fabrication of the upper layer of a slot coupled CPW-fed patch antenna described above. Figure 3 shows a photograph of the fabricated CPW-fed microstrip probe micromachined horn antenna.



Figure 3: Photograph of a microstrip probe micromachined horn antenna.

Characterization and Measurement

Both return loss and radiation pattern of a microstrip probe horn antenna have been measured. The results are shown in figures 4 and 5. Although the structure is based on a non-optimized design it shows satisfactory characteristics.

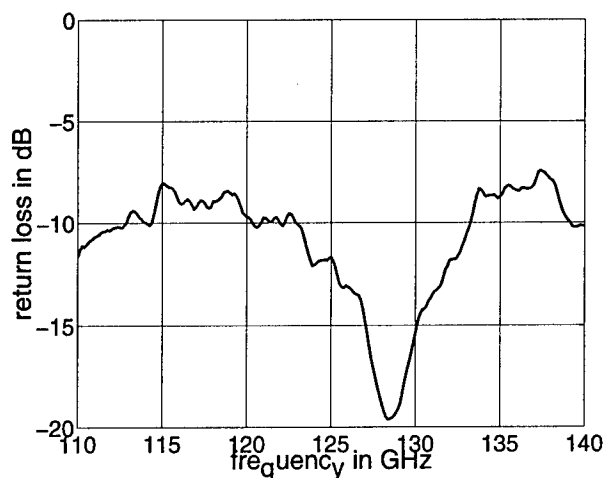


Figure 4: Measured return loss of a microstrip probe micromachined horn antenna.

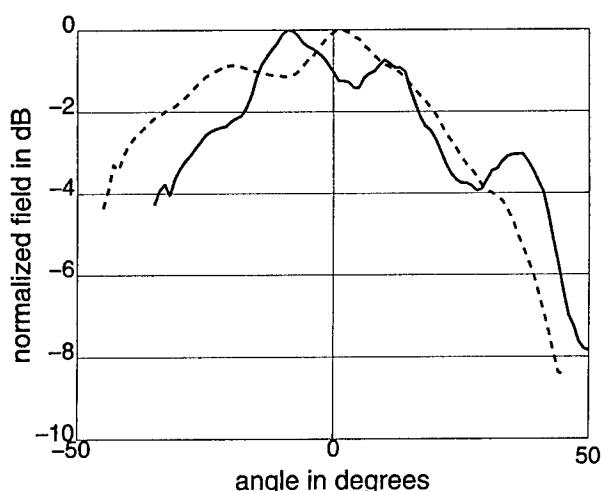


Figure 5: Measured radiation pattern of a microstrip probe micromachined horn antenna: E-plane (solid line) and H-plane (dashed line), $f = 125$ GHz.

Conclusions

Two different types of planar antennas based on thin HMDSN-membranes are presented. First measurements show satisfactory characteristics although the fabricated antenna is based on a non-optimized design. These results promise good performances for optimized structures. The antennas are fed by coplanar lines based on thin dielectric membranes. There-

fore, low-resistive silicon substrates can be used. Furthermore, the direction of maximum radiated power is perpendicular to the plane of the CPW-feedline indicating a good applicability for power combining applications. An integration of planar antennas and impatt oscillators to a multi-element power combining array will be part of future work.

Acknowledgement

The authors are indebted to the Deutsche Forschungsgemeinschaft for financial support.

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